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SOIL BIODIVERSITY, ROOT HERBIVORY AND CARBON AND NITROGEN CYCLING IN GRASSLAND SOILS

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Abstract

This paper describes research on the relationships between grassland management practices and the diversity of biological communities in soil. Observations are being made in field trials with applications of nitrogen and lime and of insecticide to an original diverse sward and to a single species grass re-seed. The treatments are designed to produce different degrees of diversity in communities of soil animals and microbes. Assessments are being made over three years of the effects on the populations, activity and diversity of root-feeding animals, arbuscular mycorrhizal fungi, soil bacteria, fungi and micro fauna, including non-plant feeding nematodes. Associated laboratory experiments assess the effects of root herbivores with different feeding sites and mechanisms on the quality and quantity of rhizosphere deposition and it relationship to microbial communities. In this way, we shall

develop an understanding of the relationships between root-herbivory and soil biodiversity and between of biodiversity and soil energy and nutrient transformations.

Keywords: bacteria, fungi, herbivory, rhizodeposition, soil animals.

Introduction

Soil flora and fauna variously affect energy flows and nutrient cycling in soils. The availability of carbon (C) is a key feature controlling microbial growth and hence nutrient cycling. Perennial grassland soils with continual root turnover, as well as litter additions, develop rich microbial and animal communities. Root browsing by invertebrates, in particular, increases the rate of turnover of root material, releasing C and nitrogen (N) (Murray and Clements, 1998). Other animals, including nematodes, feeding in or on roots or root parts also affect C and N rhizodepositions (Bardgett *et al.*, 1999). In addition, arbuscular mycorrhizal (AM) fungi also transfer carbon from plants into the soil.

We are investigating the effects of management practices on root-feeding animals and AM fungi in an upland grassland site to quantify their impacts on carbon supply to the soil and hence on the communities and activities of micro flora and fauna. These observations on energy flows are being extended to test how nitrogen cycling is affected by the management practices that lead to reduced soil biodiversity and changed C resources.

Materials and methods

Our principal field trial is the Rigg Foot Experimental Site at Sourhope near Kelso, Scotland, UK. This is part of the UK Natural Environment Research Council's Soil Biodiversity Thematic Programme. The site is representative of mid-altitude upland grassland on base-poor, mineral soils. The original vegetation, mapped in detail as part of the NERC programme, corresponds most closely to National Vegetation Category U4d, a *Festuca ovina-Agrostis capillaries–Gallium sax tile* grassland, *Luzula multiflora-Rhytidiadelphus loreus* sub community. The trial consists of 5 replicate blocks arranged in downs lope environmental gradients and was initiated in May 1999. In each block, we are sampling 3 main plots with treatments allocated at random, each with a superimposed and sub plot treatment. The main treatments are: untreated (control), a pesticide (chlorpyrifos) applied four times during each growing season at 720g/ha and a combined nitrogen (NH4NO3 at 120kg/ha) and lime (CaCO3 6t/ha) treatment applied at the start of each growing season. The sub-treatment was removing turf from 3 x3m and re-sowing these with perennial ryegrass (*Lolium perenne*). Vegetation is mowed and removed from all plots five times a year between May and September. Soil samples are taken three times per year and examined to quantify and identify macro-invertebrates, smaller root feeding insects, nematodes including those in all trophic groups, microbes (community metabolic profiles, activity, diversity and counts) and AM fungi associated with roots. In addition, root distributions, dynamics and sites of invertebrate feeding and mycorrhizae are visualised using a camera system through mini-rhizotron tubes installed in the plots. Observations on N dynamics will be made on this same site and will be compared with similar treatments imposed on more intensively managed grassland on a more fertile soil.

A series of laboratory experiments under controlled conditions is being conducted to determine the responses of roots and the effects of changes in root exudation resulting from root feeding and mycorrhizal infection. These experiments use root-feeding organisms isolated from the field trial site and determine their impacts on the quantity and quality of the carbon in root exudates. Exudates with different qualities then are used to compare their effects on microbial community functioning and diversity. The same experimental conditions will be used to investigate nitrogen turnovers in response to root herbivory and AM fungi.

Results and Discussion

The observations from the field trial will be analysed after three years to investigate relationships between the population and diversity data for all groups. Initial samples indicated the likely importance of macro root herbivores, including tipulid, bibionid and scarabid larvae. The nematode community includes known plant parasites: species with different modes of feeding in and on roots have been established *in vitro* laboratory cultures. Insecticide treatment significantly reduced insect biomass and also root biomass and number, perhaps indicating a compensatory root growth response in the presence of more invertebrates. Nematode numbers were not affected. The N and lime treatment increased both root birth and death rates, increasing the input of material to the detrital food web.

Tipulid larvae have been used in a laboratory experiments in which *Agrostis capillaris, Lolium perenne,* and clover *Trifolium repens* were separately grown in microcosms. Larvae fed in contrasting ways on different plant species, resulting in an altered pattern of C and N within the soil. Where larvae fed on roots, there was a change in the collected root exudates compared with those from uninfested plants. After application of these exudates to soils, changes in the metabolic profiles and structure of the soil microbial communities were assessed using community-level physiological profiling and PLFA. In other experiments, an increase in the number of pseudomonads was linked to a greater utilisation of certain carbon compounds in soils where larva had been grazing roots. In the field samples, spores of AM fungi and colonised root fragments have been found within tipulid larvae.

The quantity and quality of organic compounds released from roots are plant species specific, and different root herbivores affect their release in specific ways. Root exudation also increases following defoliation and can change the microbial community structure from one more dominated by fungi when undefoliated to one predominantly of bacteria when defoliated.

These field studies will also be interpreted in the light of these experimental observations to increase our understanding of soil biodiversity and function in the rhizosphere. The NERC Thematic Programme will also provide a broader framework for the application and interpretation of our data. This should make possible a consideration of the associations between grassland production and biodiversity. The combination of field and laboratory studies should provide insight into the mechanisms that maintain or reduce biodiversity in grassland soils.

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